explicit functions of X, Y, Z, x, y, z, or the equations (31) transformed into explicit functions a, e, η, L, A, B, and their coefficients of F_k, G_k, H_k, f_k, g_k, h_k.

It may be remarked that the preceding method has been already employed to deduce some remarkably interesting and important theorems with regard to the terms of long period in the mean longitude. From their form it is obvious that any single term or set of terms can be determined by themselves, so that the method is peculiarly well adapted for determining the terms of long period which converge slowly and require the fourth and fifth powers of the disturbing forces to be taken into consideration. In a subsequent communication I hope to be able to deduce by its aid some important theorems with regard to the secular inequalities in the motion of the planets depending on the third and fifth powers of the disturbing forces.

London,
December 9, 1878.

Note on the Presence of Particles of Meteoric Dust in the Atmosphere. By A. C. Ranyard, Esq.

In a Paper* read before the British Association in 1852, Professor Andrews announced that he had discovered particles of native iron in the basalt of the Giant's Causeway. Having reduced portions of the rock in a porcelain mortar to a tolerably fine powder, magnetic particles were collected by passing a magnet several times through the powder. The particles adhering to the magnet were then placed under the microscope and moistened with an acid solution of sulphate of copper. On some of them copper was deposited in a manner which indicated the presence of native iron. Professor Andrews appears to have suggested that the particles of native iron may have been derived from meteors which fell when the basalt was in a plastic condition.

In 1867 Dr. T. L. Phipson published a book entitled *Meteors, Aerolites, and Falling Stars*, in which he states† that he had frequently exposed to the wind a sheet of glass covered with some transparent mucilaginous substance in order to catch the particles of dust floating in the air. He says: "I have found that when a glass covered with pure glycerine is exposed to a strong wind late in November, it receives a certain number of *black angular particles*, some three or four of which may be thus collected in the space of a couple of hours. The experiment being made far in the country, away from the 'smuts' of a town, the black particles show themselves all the same. They are, however, not soot or charcoal; they can be dissolved in strong

* *Brit. Assoc. Reports* for 1852. Part II. pp. 34, 35. † *See* pp. 229, 230.

hydrochloric acid, and produce yellow chloride of *iron* upon the glass plate." He continues: "Although I have made this experiment at various periods of the year, and in different countries, it is only in the winter months that the black particles, giving with hydrochloric acid chloride of *iron*, have been met with."

Towards the end of 1871 Dr. Nordenskjöld collected some apparently pure snow which fell in the neighbourhood of Stockholm during a heavy snowstorm.* On melting a cubic metre of the snow collected, towards the end of the fall, he found that it left a black residue, from which he was able to extract with a magnet particles which, when rubbed in an agate mortar, exhibited metallic characters, and on being treated with acid proved to be iron.

In 1872 Dr. Nordenskjöld obtained some snow from off the ice of the Rantajerwi, at a spot which is separated by a dense forest from the nearest houses at Evoia, in Finland. When melted the snow yielded a soot-like residue, which under the microscope was found to consist of white or yellowish white granules, with a black carbonaceous substance, from which the magnet removed black grains, which when rubbed in a mortar were seen to be iron.

The Arctic Expedition of 1872 presented an opportunity for the collection of snow in a region removed as far as possible from human habitations. On August 8 the snow covering the drift ice, at lat. 80° N. and long. 13° E., was observed to be thickly covered with small black particles, while in places these penetrated to a depth of some inches the granular mass of ice into which the underlying snow had been converted. Magnetic particles were abundant, and their power to reduce copper sulphate was established. Again, on September 2, in lat. 80° N., long. 15° E., the ice-field was found covered with a bed of freshly fallen snow 50 mm. thick, then a more compact bed 8 mm. in thickness, and below this a layer 30 mm. thick of snow converted into a crystalline granular mass. The latter was full of black granules, which became grey when dried, and exhibited the magnetic and chemical characters already referred to; they amounted to 0·1 to 1·0 millegramme in a cubic metre of snow. Analysis of some millegrammes enabled Dr. Nordenskjöld to establish the presence of iron, phosphorus, cobalt, and probably nickel.

During the years 1874, 1875, and 1876 M. Tissandier published in the *Comptes Rendus*,† an interesting series of papers on his examination of atmospheric dust. He showed that in the dust deposited upon the towers of the Church of Notre Dame, as well as in the solid matter deposited from rain-water, there were metallic particles containing iron, nickel, and cobalt. On examining these particles under the microscope, he found that they were very similar in appearance to particles which he was

* *See Comptes Rendus*, lxxvii., 463.

† *See* the Numbers for March 28, 1874; January 4, 1875; October 4, 1875; and July 3, 1876.

able to detach by friction from the surface of meteorites, and he concludes that they are the solidified metallic rain detached from meteoric masses during their passage through the atmosphere.

Dr. Walter Flight published, in the *Geological Magazine* for March and April 1875, an important paper upon meteoric dust, which has since been reprinted in the *Arctic Manual.* After referring to Dr. Nordenskjöld's observations, he remarks that the dust from the polar ice north of Spitzbergen bears a great resemblance to a substance termed *cryoconite* "which was found in Greenland in 1870 very evenly distributed, in not inconsiderable quantity, on shore ice, as well as on ice thirty miles from the coast and at a height of 700 metres above the sea. The dust of both localities has probably a common origin. The cryoconite is chiefly met with in the holes of the ice, forming a layer of grey powder at the bottom of the water filling the holes. Considerable quantities of this substance are often carried down by streams which traverse the glacier in all directions. The ice hills which feed these streams lie towards the east, on a slowly rising, undulating plateau, on the surface of which not the slightest trace of stone or larger rock masses was observed. The actual position of this material, to which Dr. Nordenskjöld has given the name of cryoconite (κρύος ice, and κόνις dust), in open hollows on the surface of the glacier, precluded the possibility of its having been derived from the ground beneath."

After describing the chemical composition of cryoconite, Dr. Flight continues: "The origin of cryoconite is highly enigmatical. That it is not a product of the weathering of the gneiss of the coast is shown by its inferior hardness, indicating the absence of quartz, the large proportion of soda, and the fact of mica not being present. That it is not dust derived from the basalt area of Greenland is indicated by the subordinate position iron-oxide occupies among the constituents, as well as by the large proportion of silicic acid. We have then to fall back on the assumption that it is either of volcanic or cosmical origin." . . . . "The cryoconite, whencesoever it comes, contains one constituent of cosmical origin. Dr. Nordenskjöld extracted, by means of the magnet, from a large quantity of material sufficient particles to determine their metallic nature and composition. These grains separate copper from a solution of the sulphate and exhibit conclusive indications of the presence of cobalt (not only before the blowpipe, but with solution of potassium-nitrite), of copper, and of nickel, though in the latter case with a smaller degree of certainty, through the reactions of this metal being of a less delicate character."

In 1876 Mr. John Murray published a paper in the *Proceedings of the Royal Society of Edinburgh*,* in which he gave an account of his examination of the deposits found at the bottom of the oceans and seas visited by H.M.S. *Challenger*. In many of

* Vol ix., pp. 247-262.

the deep sea clays Mr. Murray found numerous magnetic particles, some of which he extracted by means of a magnet carefully covered with paper. On placing them under a microscope and moistening with the acid solution of sulphate of copper, he found that copper was deposited on some of the particles. From this and the circumstance that the particles bore a strong resemblance to particles found on the "mammillated outer surface of the Cape Meteorite," Mr. Murray concluded that the particles had a cosmic origin.

He suggests that the reason meteoric particles are found in such abundance in the deep sea clays is that at the bottom of the ocean far from land such particles would not be washed away or so rapidly covered up as in the case of deposits formed nearer to continents, and they would consequently appear to form a larger proportion of the deposited matter. He also suggests that the nickel present in meteoric iron would greatly retard the oxidation of such particles. Professor Alexander Herschel has, I understand, examined under the microscope some of the particles extracted by Mr. Murray, and concurs with him in the opinion that they probably have a cosmic origin.

In September 1876 Mons. E. Yung published a paper* entitled "Étude sur les Poussières cosmiques." He gives a plate showing iron particles which he had found in snow that fell at the Hospice of St. Bernard. During the years 1875 and 1876 he examined snow which fell on several other Swiss mountains, and in every instance found iron particles. He also extracted, by means of a magnet, globules of iron from dust collected upon the towers of churches. The iron particles which he figures in his plate are mostly spherical or tear-shaped, with projecting points and threads of metal. His observations entirely confirm those of M. Tissandier.

The above observations seem to point to a conclusion which has, I believe, been advocated for some time past by Mr. Proctor, viz. that meteoric matter is continually falling in quantities which, in the lapse of ages, must accumulate so as materially to contribute to the matter of the Earth's crust.† There can be little doubt that in the course of a year millions of meteors enter the Earth's atmosphere. A few of the larger masses reach the

* See *Bulletin de la Société Vaudoise des Sciences Naturelles.* Vol. xiv., pp. 494–506.

† The iron particles probably only form a very small part of the meteoric dust continually falling—for, of the larger masses which have been seen to fall, it has been estimated that not one in fifty is iron. Dr. Flight informs me that in the British Museum there are 202 stony meteorites, all of which have been seen to fall, and that there are only four iron meteorites which have been seen to fall. Stony meteorites consist for the most part of olivine, augite, hornblende, felspar, and other minerals, most of which are common in volcanic and metamorphic rocks, which therefore cannot be distinguished as having a meteoric origin unless they are found in masses. It is worthy of remark that all the elements which are common in meteorites are also common in the stratified rocks.

Earth's surface, but by far the greater number appear to be consumed in the higher atmosphere. The above observations show that minute particles of iron frequently reach the Earth's surface without having undergone any change such as might be expected to result from their passage through the air in an incandescent state. The subject is one of considerable interest, and I therefore give an account of a somewhat incomplete experiment which I made while crossing the Atlantic at the beginning of last September. When at a distance of about 1,000 miles from the American coast, I exposed some glass plates covered with glycerine to the wind. They were placed upon a wind vane behind a tin funnel which directed a current of air upon the centre of the plate. The wind vane was mounted near to the prow of the vessel, and during the time of the exposure the wind was blowing nearly at right angles to the course of the vessel.

Four plates were exposed for periods of 30 hours, 24 hours, 18 hours, and 20 hours respectively. Immediately after the exposure the plates were placed in a box such as is ordinarily used by photographers for carrying negatives, and the whole was wrapped in paper so as carefully to exclude dust till the plates could be brought to England for examination. When the box was again opened the plates were placed under the microscope, and, at Mr. Neison's suggestion, I treated them first with dilute hydrochloric acid and then with sulphocyanide of potassium, a process which would indicate the presence of iron particles by a bright red stain.

On the plate which was exposed for 18 hours a rather large particle containing iron was found. It was of a dark brown colour and was somewhat elongated, tapering slightly towards one end, but was not angular like the particles caught by Dr. Phipson. It was clearly visible to the naked eye, and I estimated it to be between the $\frac{1}{100}$ and the $\frac{1}{150}$ of an inch in its longest diameter. There were other traces of iron upon the plates, but only in very minute quantities, always in connection with minute hairs and cells which had lodged in the glycerine. I do not feel satisfied with the experiment; for although the plates were carefully cleaned and the glycerine made use of showed no traces of iron, the box in which the plates were carried had been lying about in Professor Henry Draper's laboratory in New York, and I omitted to make sure that it was perfectly free from dust before making use of it. On another occasion I would recommend that the box in which the plates are to be carried should be carefully cleaned and coated on the inside with glycerine. A box without a lock and with brass hinges should be made use of. It might also be worth while to vary the experiment by exposing a magnet to the wind with the poles covered with tinfoil. On removing the tinfoil the magnetic particles should be allowed to fall on a plate covered with glycerine, which could be kept for examination.

There can be little doubt that the air up to a great height above the Earth's surface is impregnated with dust. The sky as seen from the highest mountains appears of a dark blue, which indicates the presence of particles small compared with the wave length of light. It has usually been assumed that these particles must have been carried upwards from the Earth's surface by convection currents, but Professor Tyndall's experiments in Switzerland tend to show that the higher air is comparatively free from germs. I would suggest that the blue colour may be caused by dust derived from the débris of meteors, the smaller particles of which may possibly occupy months or even years in falling to the Earth's surface.

Much evidence has been collected by Professor von Niessl and others which tends to show that many of the larger meteoric masses enter the Earth's atmosphere with velocities which indicate that they are moving in hyperbolic orbits, and consequently do not belong to the solar system. It seems therefore probable that at all events a certain proportion of the meteoric dust is derived from sources outside the solar system. The Earth and planets, as they are carried along with the Sun in his motion through space, would thus receive a larger proportion of meteoric matter on their northern than on their southern hemispheres, and I would suggest, as a theory worthy of consideration, that this may account for the preponderating mass of the continents in the northern hemisphere of the Earth, and for the fact, which has so frequently been pointed out by physical geographers, that the great terrestrial peninsulas all taper towards the Southern Pole.*

The experiments of Professor Arthur Wright, of Yale, show that when meteoric masses are heated, considerable amounts of occluded gas are given off. We shall therefore, in considering the results which must follow from the continuous fall of meteoric matter, have to take into account the fact that gaseous matter is probably continually being added to the atmosphere. If the amount of gaseous matter taken from the air and stored up in a solid form by the agency of plants and animals, and by the oxi-

* The following facts with regard to the Moon and the planet *Mars* may also have some connection with the unequal addition of foreign matter on their northern and southern hemispheres. On the Moon the volcanic action has been decidedly more intense in the southern than in the northern hemisphere, and it will also be noticed that the great crater ranges run mostly north and south. On the planet *Mars*—if we adopt the delineation of the seas and continents given by Proctor in his map, which was chiefly made from the drawings of the planet by Dawes—there is, as on our Earth, a greater proportion of ocean surface in the southern than in the northern hemisphere. On *Mars* the land surface is decidedly greater than the ocean surface, so that the seas appear reduced to mere lakes and narrow inlets; but it will be noticed that these have their broadest expansion in the southern hemisphere, and that what has been termed the equatoreal girdle of continents has its medial line decidedly to the north of the Martial equator.

dation of mineral substances, does not counterbalance the amount continually being added to the atmosphere from meteors, together with the supplies derived from volcanic vents and from other sources from which the atmosphere may be recruited, it will be evident that the total amount of the atmosphere must either be increasing or decreasing. And the point to which I wish to draw attention is that such an increase or decrease would in time serve to account for great changes of temperature at the Earth's surface. If we suppose the Earth to pass through a region of space where there are comparatively few meteors, the height of the atmosphere would in the course of time be greatly decreased, and we should have a temperature at the sea level corresponding to the present temperature of our mountain-tops. In the language of geologists, a glacial epoch would be the result. If, on the other hand, the Earth passed through a region of space rich in meteors, containing occluded carbonic acid gas, the atmosphere would increase in depth, and a period like the carboniferous period might be the result, in which a semi-tropical vegetation might again flourish on the coast of Greenland.

Observations of the Transit of Mercury, May 6, 1878, *and of the Occultation of Mars by the Moon, June* 3, 1878, *made at the Glasgow Observatory.* By Professor R. Grant, Director of the Observatory.

Transit of Mercury.

Observed by Mr. Arthur Bowden, Principal Assistant. The instrument used was the Ochtertyre Equatoreal of 9 inches aperture, with a magnifying power of 240 applied. The external contact at ingress was lost. As the planet advanced upon the Sun's disk, the instant of the bisection of its disk by the Sun's limb was observed to occur at $3^h\ 12^m\ 31^s$ Greenwich Mean Time. The internal contact was well seen. It occurred at $3^h\ 14^m\ 15^s{\cdot}7$ Greenwich Mean Time. A bright spot was distinctly seen on the disk of the planet a little before contact. It was well defined and appeared of the same colour as the Sun. When the planet had wholly entered upon the Sun the spot did not appear so bright, but as the Sun was all the time covered by a thin cirrus of constantly varying density, the difference in brightness of the spot may have been attributable to that cause. No indication of a ligament was perceptible at the time of the planet's entrance upon the Sun's disk, but immediately after internal contact the limb of the planet exhibited an elongation or distortion towards the Sun's limb. This appearance continued visible for about ten seconds after contact. The bright spot was seen only once after the